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(54) **Method of coupling radiation in an infrared detector and device herefor.**

(57) A method for coupling radiation in an infrared detector of the kind which uses quantum wells that are comprised of thin layers of, e.g., gallium arsenide (GaAs) surrounded by aluminium gallium arsenide (AlGaAs). The invention is characterized in that a two-dimensional crossed grating (6), a so-called 2-D grating, is constructed on the top of the detector mesa of the detector on the side opposite the surface through which incident light (5) enters the detector. The grating (6) is caused to spread the incident light in different directions. According to one preferred embodiment, the detector also includes a cladding layer (14) which, together with the crossed grating, forms a wave guide.

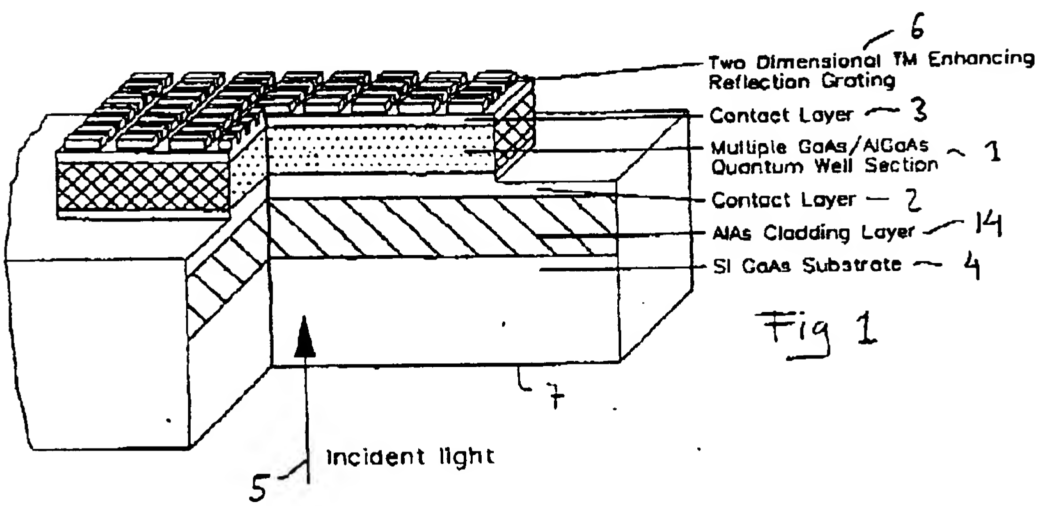

Fig 1

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The present invention relates to a method of coupling radiation in an infrared detector, and an arrangement herefor.

Long-wave infrared detectors based on quantum wells have been found to be extremely responsive and efficient. The performance of such infrared detectors is close to that achieved with commercial mercad-detectors, i.e. mercury cadmium telluride-detectors. The wavelength response is a narrowband response, and can be selected between 3 and 15 micrometers.

Infrared detectors, IR-detectors, which use quantum wells are comprised of a thin layer of, e.g., gallium arsenide (GaAs) surrounded by aluminium gallium arsenide (AlGaAs). The most common type of IR-detector comprises 50 such quantum wells, each having a thickness of about 5 nm.

When infrared radiation of the correct energy impinges on the detector, electrons are excited to a state in which they can move readily from quantum well to quantum well, causing current to flow. The wavelength at which the detector has its maximum response may be varied intentionally, by appropriate choice of the dimensions and chemical composition of the quantum wells.

The most common detector is photoconductive. It is also possible, however, to manufacture photovoltaic detectors.

Quantum well detectors are either manufactured in accordance with the MOVPE-technique (metal organic gasphase epitaxy) or in accordance with MBE-technique (molecular beam epitaxy).

One serious problem common to quantum well detectors that are based on so-called intersub band transitions in the conductor band is that they are sensitive solely to IR-radiation whose electrical field vector has a component which is perpendicular to the quantum-well plane. This limits the degree of quantum efficiency and renders the majority of detector configurations sensitive to polarization. In particular, the detector is not sensitive, or responsive, to radiation which is incident perpendicular to the quantum-well layer.

The present invention solves this problem and provides a technique where the detector has a high degree of quantum efficiency, irrespective of the angle of the incident radiation, and where the detector is not sensitive to the polarization direction of the radiation.

Thus, the present invention relates to a method for coupling radiation in an infrared detector of the type which uses quantum wells that are comprised of thin layers of, e.g., gallium arsenide (GaAs) surrounded by aluminium gallium arsenide (AlGaAs), and is characterized in that a two-dimensional reflection grating, a so-called crossed grating, is formed in the top of the mesa of the detector, i.e. the quantum-well structure of the detector, on the side opposite to the surface through which incident light enters the detector, said grating causing the incident light to spread in different directions.

The invention also relates to an arrangement of the kind defined in Claim 5 and having the characteristic features set forth therein.

The invention will now be described in more detail, partly with reference to an exemplifying embodiment thereof illustrated in the accompanying drawing, in which

- Figure 1 is a perspective, partially cut-away view of a detector in which the invention is employed;
- Figure 2 is an explanatory drawing, in which the grating shown in Figure 1 is illustrated from beneath; and
- Figure 3 is a cross-sectional view of a structure according to Figure 1.

Figure 1 illustrates a detector in which the invention is applied. The detector is an infrared detector which functions to detect infrared radiation. The detector is of the kind which uses quantum wells, said wells comprising thin layers of, e.g., gallium arsenide (GaAs) surrounded by aluminium gallium arsenide (AlGaAs). In Figure 1, the reference numeral 1 identifies a multiple of such quantum-well layers. For instance, the layer may comprise 50 thin layers of GaAs and AlGaAs which together have a thickness of 1.7 micrometers. A respective contact layer 2 and 3 is provided beneath and above the quantum-well layer. The detector is built-up on a substrate 4 of semi-insulating gallium arsenide (GaAs). Incident light is intended to impinge from beneath in Figure 1, as shown by the arrow 5.

In accordance with the invention, there is provided a two-dimensional reflection grating 6, a so-called crossed grating or doubly-periodic grating, on the top of the detector mesa 1 of the detector, i.e. on the quantum-well structure of the detector, on the side opposite to that surface 7 through which incident light 5 is intended to enter the detector. The reflection grating is comprised, for instance, of etched gallium arsenide with an overlying metal layer. The grating 6 is intended to spread the incident light in different directions.

The grating is constructed so as to spread light in four directions, namely (1,0), (- 0,0) (0,1) and (0, -1). These directions are designated (1 0)-directions in the following. In order to achieve good absorption, it is optimum to lie close to the so-called cutoff of these directions, where the spread angle is close to 90° and the wavelength in vaccum is equal to N x d, where N is the refraction index and d is the grating constant.

However, the spread radiation may either be TE (transverse electric) with the electric field vector lying parallel with the quantum well plane and the grating plane. There is no quantum-well absorption in this case. Alternatively, the field vector may be directed perpendicularly to this direction, i.e. TM (transverse magnetic), in which case quantum-well absorption will

take place. The dimensions of the crossed grating can be chosen by the skilled person so that spread radiation with TM-polarization is enhanced at the cost of radiation with TE-polarization, which optimizes absorption.

Furthermore, reflexes with the order (0 0) can be minimized since this does not give rise to absorption either.

The aforedescribed is illustrated in Figure 2, which shows the grating from beneath and which indicates the direction of incident light with the arrow 5. Incident light or radiation may be non-polarized or polarized. In both cases, the electric field can be divided into an x-component (Ex), which is indicated by a solid line 8 between two solid circles, and a y-component (Ey) which is indicated with a solid line 9 between two hollow squares. The magnitude and direction of the electric field are given respectively by the length and the direction of the solid lines.

As shown in Figure 2, the incident radiation, whose field vector is parallel with the grating plane, is converted by the influence of the grating so that a large component TM-radiation, where the field vector is perpendicular to the grating plane, is formed and thus give rise to absorption; see the beams 10, 11. In the case of the spread light, the electrical fields originating from the x-direction of the incident radiation are shown as such, i.e. with a solid line between two solids circles, whereas the electric fields originating from the y-direction are shown with a solid line between two hollow squares.

In this way, the grating couples the incident radiation effectively to the quantum wells through said reflection.

Consequently, the grating renders the detector insensitive to how the incident radiation is polarized.

According to one preferred embodiment, the crossed grating is configured with square or hexagonal symmetry. This renders the detector totally insensitive to the polarization of the incident light.

It can be shown that the precise form of the grating profile is not critical in obtaining a high degree of quantum efficiency.

For example, the grating may consist of parallelepipedic bodies, as illustrated in Figure 1, measuring 0.9 x 2.1 x 2.1 micrometers.

The grating, however, may alternatively comprise circular bodies in the plane of the grating, or bodies of some other shape.

Although not shown, a metal layer is provided above the grating for reflecting the incident light that falls onto the grating back onto the quantum-well layer 1. This layer will be a good conductor, for instance a gold, silver or aluminium layer.

According to one most preferred embodiment, a so-called cladding layer 14, i.e. a mirror having a low refraction index, is mounted beneath the quantum-well structure 1. This layer may be an aluminium arsenide layer or, alternatively, an aluminium gallium arsenide layer. The layer 14 has a low refraction index, which gives total reflection. Figure 3 illustrates how incident light or radiation 5 is reflected onto the grating 6 and onto the cladding layer 14, causing the light to pass through the quantum wells a number of times, thereby greating increasing the degree of quantum efficiency. Thus, it is highly preferable to combine the grating with said cladding layers. The grating and the cladding layer therewith define a waveguide. The cladding layer may have a thickness of 3 micrometers for instance.

According to an alternative embodiment there is no layer corresponding to the said layer 14, but the mirror consists of the ambient atmosphere, where the refraction index of the atmosphere gives total reflection. The atmosphere can for example be air or any other suitable gas.

According to this embodiment there is no cladding layer 14 and there is no substrate 4. Instead the control layer 2 forms the underside. However, a thin layer of gallium arsenide (AlGaAs) can be applied on the contact layer 2, which layer of AlGaAs then forms the underside of the structure.

A degree of quantum efficiency as high as 80-90% is obtained with the described method and arrangement.

The reflection grating 6 together with the cladding layer 14 also greatly reduces the occurrence of so-called cross-talk between adjacent detector elements in an array of such elements.

It is obvious that the present invention solves the problems mentioned in the Introduction.

A number of exemplifying embodiments have been described in the aforegoing. It will be understood, however, that the arrangement can be modified with respect to material, the configuration of the grating, etc., without departing from the inventive concept of using a grating to enhance the degree of quantum efficiency. The present invention shall not therefore be considered restricted to the aforedescribed and illustrated exemplifying embodiments thereof, since modifications can be made within the scope of the following claims.

Claims

1. A method for coupling radiation in an infrared detector of the kind that uses quantum wells which comprise thin layers of, e.g., gallium arsenide (GaAs) surrounded by aluminium gallium arsenide (AlGaAs), characterized by a two-dimensional reflection grating (6), a so-called crossed grating, constructed on the top of the mesa of the detector on the side opposite to the surface through which incident light (5) is intended to enter the detector, said grating (6) being caused to

spread the incident light in different directions.

2. A method according to Claim 1, **characterized** by constructing the grating (6) to spread light in four (1 0)-directions, preferably close to the so-called cut-off of said (1 0)-directions, where the spread angle is close to 90°.

3. A method according to Claim 1 or 2, **characterized** by that a mirror of low refraction index is present beneath the quantum-well structure (1), preferably a so-called cladding layer (14).

4. A method according to Claim 1, 2 or 3, **characterized** by giving the crossed grating (6) a quadratic or hexagonal symmetry.

5. An infrared detector for detecting infrared radiation, said detector being of the kind which uses quantum wells that are comprised of thin layers of, e.g., gallium arsenide (GaAs) surrounded by aluminium gallium arsenide (AlGaAs), **characterized** in that a two-dimensional reflection grating (6), a so-called crossed grating, is located on the top of the mesa of the detector on that side which is opposite to the surface through which incident light (5) is intended to enter the detector, said grating (6) being constructed to spread the incident light in different directions.

6. An infrared detector according to Claim 5, **characterized** in that the grating (6) is constructed to spread light in four (1 0)-directions, preferably close to the so-called cut-off of the (1 0)-directions, where the spread angle is close to 90°.

7. An infrared detector according to Claim 5 or 6, **characterized** in that a so-called cladding layer (14), i.e. a mirror of low refraction index, is provided beneath the quantum-well structure (1).

8. An infrared detector according to Claim 5, 6 or 7 **characterized** in that the crossed grating (6) is constructed with square or hexagonal symmetry.

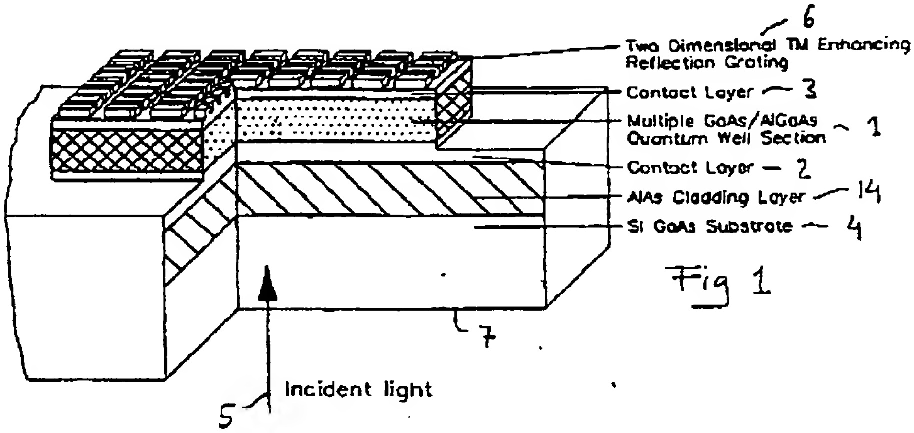

Fig 1

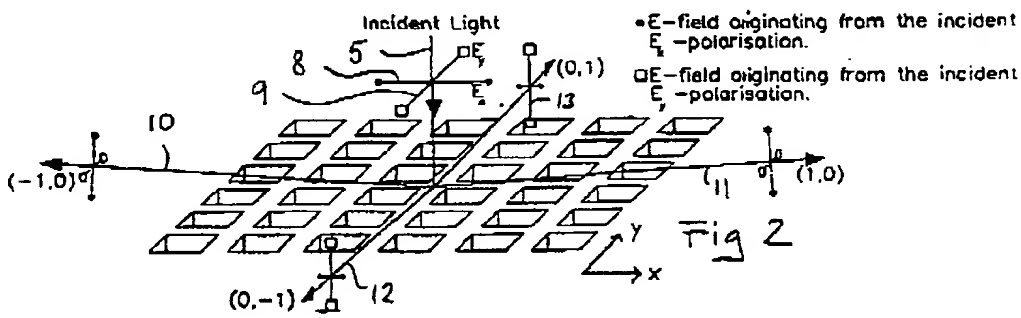

Fig 2

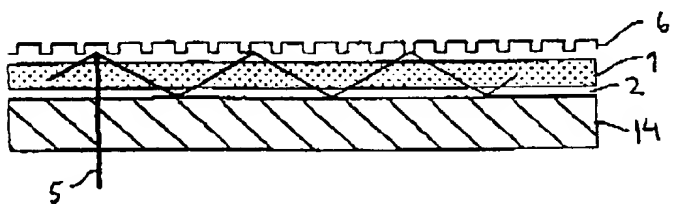

Fig 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 85 0073

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	APPLIED PHYSICS LETTERS. vol. 23, no. 12, 19 September 1988, NEW YORK US pages 1027 - 1029; K.W.GOOSSEN ET AL.: 'GRATING ENHANCEMENT OF QUANTUM WELL DETECTOR RESPONSE' * the whole document *	1,3,4,5, 7,8	H01L31/0236 H01L31/0352
A	TECHNICAL DIGEST OF THE 5TH INTERNATIONAL PHOTOVOLTAIC SCIENCE AND ENGINEERING CONFERENCE 26 November 1990, KYOTO, JP pages 587 - 590; H.KIESS ET AL.: 'LIGHT TRAPPING IN SOLAR CELLS USING SUBMICRON GRATINGS' * figures 1A,1B *	1,4,5,8	
A	GB-A-2 071 414 (ELEKTRONIKCENTRALEN) * figures 4-7 *	1,4,5,8	
A	EP-A-0 317 061 (EXXON RESEARCH AND ENGINEERING COMPANY) * figures 1,2 *	1,4,5,8	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H01L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	09 JULY 1992	LINA F.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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